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High Purity Aluminum Policy Technical Update

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SUR/FIN 2010 conference

15 June 2010

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
15 JUN 2010		**00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
High Purity Aluminum Policy Technical Update	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Research, Development and Engineering Command ,Tank Automotive Research, Development and Engineering Center (TARDEC),6501 E. 11 Mile Road,Warren,MI,48397**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
SUR/FIN 2010, 14-17 June, Grand Rapids, MI. Sponsored by SERDP/ESTCP.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**19**	

Agenda

- DoD and TACOM direction - Go Green
- Overview of draft high purity aluminum policies
- Path forward
- Testing of aluminum coatings on electrical shell connectors and fasteners
  - Test results
  - Future testing
  - Coating thickness variation of shell connectors
  - Lessons learned
- High purity aluminum and threaded fasteners technical update

Overview of draft high purity aluminum policies

Revision to original draft

- This memorandum provides guidance to the DoD Components on the replacement of cadmium plating for fasteners and electrical connectors in the procurement and maintenance of DoD materiel. **This policy applies to parts that are currently coated with cadmium.** DoD fasteners and electrical connectors currently plated with cadmium shall be procured with high purity deposited aluminum coatings without hexavalent chromium treatment except where specific requirements dictate a particular coating (including cadmium if other alternatives are technically unacceptable).

Path forward

- Continue with implementation effort
  - Technological
    - Looking at other methods e.g. ionic liquid plating
    - Standardizing post-treatments for durability, corrosion, and lubricity
  - Business case
    - Automation alley is assisting in developing new sources
    - Contracted business case analysis with US2
  - New source coming online with Title III funding in Michigan
- Get consensus on test protocols for new product introduction

Testing of aluminum coatings on electrical shell connectors and fasteners

- Test results
  - CTC shell connectors and fasteners
- Future testing
  - Discussion with Boeing to identify relevant testing
    - Scribing
    - Coating thickness of test sample
    - Test methods (corrosion, adhesion, torque tension, friction)
    - Environmental, laboratory, both
- Lessons learned
  - Qualification tests do not always predict service usage
  - Community needs consensus on test protocol to better predict service life (developmental & qualification)
    - Over-reliance on B117 and its correlation to real use
    - Propose combination of laboratory and outdoor exposure
    - Thickness control, scribing
    - What does test really mean

Thickness variation of test sample coatings

Panel Coating System	Vendor-Provided Coating Thickness Range (mils)	Average Measured Thickness (mils)
Cadmium / hex Cr	0.8 to 1.5 per side	0.43
		0.30
		0.30
Al / TCP	0.6 to 1.0 per side	0.05
		0.02
		0.01
ZnNi / TCP	0.8 to 1.5 per side	0.96
		0.92
		0.90
ZnNi / NCP	0.7 to 1.2 per side	0.97
		0.92
		0.77
SnZn / TCP	0.2 minimum	0.27
		0.35
		0.38
SnZn / NCP	0.2 minimum	0.35
		0.43
		0.48
Durmalon	(none provided)	1.60
		1.61
		1.44
PIN	0.8 to 1.5 per side	1.38
		1.35
		1.40

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High Purity Aluminum and Threaded Fasteners Technical Update

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Threaded Fasteners / Issues

- Stryker wheel stud field exposure
- Future work with high purity deposited aluminum
- Concurrent Technologies Corporation threaded fastener study
- Coating thickness measurement systems analysis
- Conclusions / Recommendations

Stryker Wheel Fasteners
Seven months in Hawaii

Zinc-Plated
Plus CARC Topcoat

Electroplated
High Purity Aluminum with TCP

Future Work with High Purity Deposited Aluminum

- E-coat
- Anodize
- TCP
- Friction modifiers

Fastener Finish Study
Concurrent Technologies Corp.

- Two fastener sizes: $^{3}/_{8}$-inch and $^{1}/_{2}$-inch
- Six fastener finishes evaluated for…
  - Clamp load
  - Affect of Corrosion on Run-on torque at fixed clamp load
  - Affect of Corrosion on Breakaway torque

Fastener Finish Study
Concurrent Technologies Corp.

FINISH	POST-TREATMENT	SEALER
Cadmium	Hexavalent Chromium	Enseal C22
Zinc	Hexavalent Chromium	Enseal C22
Zinc	Trivalent Chromium Process (TCP)	Enseal C22
Zinc Nickel	Trivalent Chromium Process (TCP)	Enseal C22
Aluminum (High Purity)	Trivalent Chromium Process (TCP)	Enseal C22
Geomet	N/A	Plus L

Torque Vs Corrosion Constant Clamp Load

GM9540P	0 Cycles	
FINISH	Run-On Torque (in/lb)	Percent Difference from Cd-Hex
Cd/Hex	1483	
Al/TCP	1455	-2%
Zn/Hex	1543	4%
Zn/Ni	693	-53%
Zn/TCP	622	-58%
Geomet	521	-65%

½-Inch Fasteners

GM9540P	20 Cycles	
FINISH	Run-On Torque (in/lb)	Percent Difference from Cd-Hex
Cd/Hex	1778	
Al/TCP	1990	12%
Zn/Hex	2019	14%
Geomet	667	-62%
Zn/TCP	655	-63%
Zn/Ni	625	-65%

Torque Vs Corrosion Constant Clamp Load

GM9540P	40 Cycles	
FINISH	Run-On Torque (in/lb)	Percent Difference from Cd-Hex
Cd/Hex	1859	
Al/TCP	2023	9%
Zn/Hex	2313	24%
Zn/TCP	901	-52%
Zn/Ni	827	-56%
Geomet	742	-60%

½-Inch Fasteners

GM9540P	60 Cycles	
FINISH	Run-On Torque (in/lb)	Percent Difference from Cd-Hex
Cd/Hex	1927	
Al/TCP	1792	-7%
Zn/Hex	2283	18%
Zn/TCP	1168	-39%
Zn/Ni	803	-58%
Geomet	671	-65%

Torque Vs Corrosion Constant Clamp Load

GM9540P	80 Cycles	
FINISH	Run-On Torque (in/lb)	Percent Difference from Cd-Hex
Cd/Hex	1704	
Al/TCP	1651	-3%
Zn/TCP	914	-46%
Zn/Ni	773	-55%
Geomet	624	-63%
Zn/Hex	N/A	N/A

- Different finish, different friction
- Different friction, different torque, @ same clamp load
- High purity aluminum closest to cadmium
- High purity aluminum least risk of affecting torque and clamp load
- Specify target coefficient of friction and test method

½-Inch Fasteners

Coating Thickness Measurement System Analysis

- Bench-top magnetic induction/eddy current coating thickness instrument
- M10.9 fasteners - quantity of ten
- Zinc-rich inorganic base + organic topcoat
- Two operators, three trials each - Randomized
- Full Factorial Design of Experiments (DOE)*

* *Fundamental Statistical Process Control – Reference Manual* by the Automotive Industry Action Group (AIAG)

Coating Thickness DOE Results

Measurement Systems Analysis	Process Variation
Repeatability (Equipment Variation)	73%
Reproducibility (Appraiser Variation)	33%
Repeatability & Reproducibility	**81%**

Gage System OK	Gage System Questionable	Gage System Must Improve
< 10%	10% - 30%	> 30%

Conclusions

Multiple Cadmium Alternatives Multiplies Risk

- Incorrect fastener installed
- Improper applied torque
- Joint failure
- Premature corrosion failure

Few Cadmium Alternatives Decreases

- Risk
- Logistics cost & complexity

Fastener & Connector Joint Test Protocols

- Community consensus needed
  - Corrosion tests that identify finish strengths & weaknesses
  - Define acceptable coating thickness for comparison testing
    - For various fastener applications
    - Establish side-by-side comparison (not necessarily identical thicknesses)
  - Other tests

Friction	Smoothness	Post-treatments
Dimensional conformity	Heat treatment	Durability
Conductivity	Strength	

- Propose Working IPT
  - DoD Research labs, commodity commands and industry